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Pitfalls in developing coastal climate adaptation responses

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ABSTRACT

Increasing awareness of the risks to coastal communities and infrastructure posed by sea level rise and possible climate-induced changes to the frequency and intensity of catchment flooding events have triggered a large number of studies that have assessed the risk, and developed a prioritisation of actions. These prioritised action recommendations are typically encapsulated in climate adaptation plans and pathways documents, risk reduction strategies, and climate action plans. These studies typically involve a vulnerability assessment task and an action prioritisation task, often performed in the same study. Most of the focus on research and method development over recent decades has been on the first task that aims to quantify the vulnerability of coastal communities and infrastructure. It is argued here that as a result of this emphasis on assessing vulnerability, at the cost of adequate consideration of response actions, along with the linear 'fix and forget' management approach to climate adaptation, has led to a lack of uptake in coastal climate adaptation studies and strategies. To this end the aim of the work presented here is to highlight common shortfalls in this fix and forget approach and in particular in the response prioritisation task. Ways that these shortfalls can be avoided, based on knowledge from decision theory, are presented.

Introduction

Over the last two decades an increasing number of climate change risk and adaptation studies have investigated potential climate change-induced impacts to coastal settlements and infrastructure. This is presumably in response to the increasing global awareness of the potential impacts of climate change delivered either through acute and sporadic natural hazards (i.e. floods, wildfires), creeping or slow-moving changes to environmental conditions (i.e. extended droughts), or interactions between both (IPCC, 2013). In such interaction cases synoptic extreme events are exacerbated by slow moving changes to underlying conditions (for example increased rainfall intensity and coastal flooding during storms potentially exacerbated by a globally warmer atmosphere).

Many of these studies have considered potential impacts to coastal areas where creeping sea level rise is expected to increase the risk profile for a number of coastal settlements (e.g. Appelquista and Balstrømb, 2014). These studies are being delivered by a variety of providers ranging from the academic and research community, to general and specialised environmental and engineering consultants. Furthermore, like any new discipline or service offering, a range of methodological approaches have been developed and applied. However to date there has been little comparison or consensus of approaches

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other than a general agreement that formal risk-based approaches are an appropriate framework for considering climate change risks (IPCC, 2014).

Given the burgeoning scientific and grey (unpublished technical reports) literature providing recommendations encapsulated in climate action plans, climate adaptation roadmaps, and capital works programs, it is reasonable to expect that a corresponding increase in real management changes would have occurred. Such expected changes might include demonstrable amendments to land-use plans, updates to engineering and construction design standards (Gibbs, 2012) and wholesale relocation of coastal settlements landwards (coastal retreat). However, as highlighted in the most recent Intergovernmental Panel on Climate Change adaptation report (IPCC, 2014), in light of the number of studies that have been performed there is a conspicuous lack of uptake and on-the-ground change. Ford et al. (2011) and Preston et al. (2011) both reached a similar conclusion following systematic analyses of climate change adaptation actions in developed nations.

There are generally two tasks performed in coastal climate adaptation pathways, strategies or policy studies. The first task typically involves assessing the vulnerability of coastal areas and individual building or asset sites. This is generally achieved by undertaking inundation modelling using numerical dynamic hydraulic and hydrodynamic flood models (Klein and Nicholls, 1999). Simpler assessments use what is known as 'bathtub' models in which a digital elevation spatial model or dataset is overlaid with a horizontal water surface of varying levels analysed within in a GIS (Geographic Information System) environment. These static bathtub type models are not recommended as ignoring the dynamics of the water movement can lead to substantial inaccuracies in predictions of water levels.

These analytical tasks typically provide insight into how likely inundation may be for each location, and what the maximum inundation depth may be for specified hazard events. This is often termed the vulnerability of particular sites and locations (Adger, 2006). Whilst there are challenges in deciding what future sea level rise and rainfall intensity, frequency and duration estimates should be used, in general this vulnerability assessment task is relatively well understood and tractable as these uncertainties are increasingly governed by practitioner guidelines and such studies are routine for the coastal and flood modelling practitioner community (e.g. Boateng, 2012).

More comprehensive versions of this task then use information on the consequence of inundation of each asset (houses, commercial and industrial sites, major civil infrastructure) at each site to estimate the risk to each asset from inundation. Risk is formally estimated from the product of the likelihood of inundation and the consequence of inundation. Consequences are commonly defined in terms of the expected cost of physical damage to assets resulting from inundation. Whilst this may be appropriate for private residences and houses, for civil assets and infrastructure and commercial properties these consequences are best assessed in terms of the loss to service levels, in accordance with the new international ISO 55,000 asset management standard.

The second task involves translating this information on either vulnerability or risk into a prioritisation of actions. This is the advisory component of the plan, strategy or study whereas the first task is primarily an information generation component. How this prioritisation tasks is undertaken is a focus of the work presented here. In particular, it is argued here that most of the method development research has focused on the first task by comparison to the second task. For example, a Web of Science search using the keywords 'climate' and 'prioritization' revealed 373 journal papers since 1995. By contrast, a search using the key terms 'climate' and 'vulnerability' revealed 6057 papers since 1991. This result is consistent with the more comprehensive analysis performed by Berrang-Ford et al. (2011). The first tasks focuses on the geophysical aspects of the problem, but the second task quickly moves into the realm of financial risk and distributional conflicts.

Inspection of a large number of these coastal climate adaptation studies published in both the scientific and the grey literature, and direct experience in authoring and reviewing a number of these studies suggests a number of commonly applied shortfalls in this second advisory task have reduced the utility and ongoing uptake of these types of coastal climate adaptation studies. The aim of the work presented here is therefore to provide an overview and categorisation of these observed shortfalls in the prioritisation task in order to stimulate discussion and underpin ongoing quality improvement of these studies.

In collating these shortfalls, along with discussions and comments from reviewers of this work, it also became apparent that many of the shortfalls are also a result of the 'fix and forget' linear management approach typically followed in climate adaption studies. This approach generally involves assessing the vulnerability or risk, managing the vulnerability or risk at a point in time through undertaking risk management initiatives, and then assuming that the risk or vulnerability has been effectively managed. Such approaches are best suited to well-understood problems featuring little future uncertainty. Therefore, as discussed below a number of the shortfalls identified here could be avoided if a more adaptive management approach was followed.

A list of shortfalls was developed by comparing common approaches to climate adaptation planning to formal risk, asset, and environmental management approaches, methods and frameworks. The identified shortfalls are clustered into the following two categories:

- Shortfalls in valuing the benefits, and to a lesser extent costs used in the prioritisation process.
- Shortfalls primarily arising as a consequence of the linear fix and forget management approach.

Common shortfalls when valuing the benefits and costs of adaptation responses

The first three shortfalls are associated with problems in valuing advantages, and costs and benefits of adaptation responses. Generic difficulties with valuing climate change and disaster risk reduction strategies are well known (i.e.

Maybee et al., 2012). For example desalination plants were constructed in a number of Australian cities towards the end of the Millennium Drought in the early 2000s in response to the extended drought conditions. As luck would have it, significant rain events followed the commissioning of many of these plants. This subsequently led to widespread political calls that the investment in these facilities was irresponsible and that no benefits from these facilities would accrue. This is in despite of the clear likelihood of future water shortages (El Saliby et al., 2009). Such short-term views or political positioning undervalue the inevitable future risk reduction benefits of these facilities.

The valuation shortfalls identified here are very specific shortfalls that commonly appear in climate adaption studies, as follows.

Direct mapping of vulnerability to priority or action responses

The first shortfall focuses on the currency of valuation that is then used in the prioritisation task.

When following the linear management framework, the most common and straightforward approach of translating or mapping information on vulnerability into a ranking or prioritisation of response actions is to directly map the vulnerability onto a prioritisation ranking and use this to develop a set of on-the-ground adaptation responses. When this is done the asset that is the most vulnerable or at-risk becomes the highest priority for response action. Correspondingly the asset least vulnerable becomes the lowest priority for action and the valuation of consequences essentially collapses into an assessment of vulnerability.

When this approach is applied based on the vulnerability alone (as opposed to the risk), it is implicitly assumed that all assets have equal value or importance. This is rarely the case which is why this approach is not recommended. This direct mapping approach also ignores the asset life span, and existing replacement or refurbishment plans, all of which can be major determinants of future risk but can also be quite uncertain. For example, an individual structure located on the site of a larger facility may be highly vulnerable to sea level rise. However, if the structure will no longer be required or will be scheduled for refurbishment before the vulnerability becomes problematic, then the overall risk or burden may be reduced and little management action required. Recommending a substantive adaptation response such as relocating the structure in this case is nonsensical as its utility will be small by the time the vulnerability becomes problematic.

If the currency of the risk assessment task has been risk (as opposed to vulnerability), which explicitly considers the consequences or impacts of climate change, then translating a ranking of risk directly into a ranking of priority for action is a more reasonable approach. However this assumes little uncertainty in the estimation of future consequences, and that the criteria for estimating the consequences well-describes the problem to be solved. For example, if the risk assessment is applied to both private and public assets, it is often implicitly assumed that these will be treated equally with regards to costs and benefits of remediation or refurbishment. In some jurisdictions, such as in the State of New South Wales in Australia, climate adaption policy explicitly states that public assets are given priority over private assets, presumably to incentivise private property owners to cover future risk through insurance. Therefore using a ranking of risk also as a ranking of actions is valid only when the consequences used in the first task are the same as the consequences to be considered when undertaking prioritisation, and these metrics of consequences are appropriate and internally consistent. Similarly, if the consequences of inundation for commercial or public good assets are assessed only by estimating the costs of repairing physical damage, this will not represent the most important and costly consequences that are generally associated with loss of service.

Direct mapping of risk to mitigation actions can also be problematic when the risk criteria used in the first risk assessment task are given emotive descriptors. This is especially the case when risk criteria are framed in terms of unacceptable or acceptable risk. This is because the concept of acceptability is highly subjective, even when tightly defined. When individuals are questioned on acceptability, unacceptability implies that individuals are personally unhappy with the balance of costs and benefits. However such an assessment is underpinned by individual willingness to accept the costs and benefits as they might implicitly accrue to themselves. Therefore when individuals are asked to assess acceptability, we tend to bias our thinking in terms of whether we personally or individually would be exposed to the costs and benefits. Hence an individual's assessment of acceptability of risks to assets that we do not own or operate is likely to be biased. In theory this problem can be overcome by obtaining a consensus view on acceptability. However, this will only be accurate if all the stakeholders are well-represented. For example, asking a local government bureaucrat, consultant or researcher what may be an acceptable risk to a major industrial facility is not likely to be appropriate or helpful.

Direct mapping of risk into a ranking of priority also ignores the fact that mitigating the risk to different assets often will have different cost-efficiencies – some risks will be high but very difficult to mitigate. How the cost of adaptation or risk management strategies is incorporated into the prioritisation needs to be considered with care. Implementation costs can either be an objective to be traded-off against other objectives, or as the single-most important criteria to be optimised.

Spatial scale

The valuation of costs and benefits of adaptation responses is heavily dependent upon the spatial scale and attributes under consideration. The approach of valuing or monetising specific costs and benefits, while appearing logical ignores the fact that communities, especially in industrialised nations consist of a mixture of public and private rights holders, most of which are likely to be self-interested, have varying social and financial status (ability to pay for adaptation) and live in assets of different ages and conditions. It needs to be remembered that that uptake of climate adaptation strategies is largely determined by the level of support or opposition given by the stakeholders, not the assets that they live in.

Consideration of the scale or granularity of responses therefore needs to not just consider assets that are physically located alongside one-another, but by considering the ownership and willingness and ability to support various adaptation options. This implies that finer spatial scales may need to be considered and when clustering adaptation strategies together, simply clustering assets located alongside one another into discrete adaptation pathways can be problematic. For example, it is becoming increasingly common for major civil and industrial facilities to have separate adaptation plans even though these are often physically embedded in or surrounded by other assets and facilities, including residential housing. This creates interaction problems as owners of different asset classes often have different incentives to act (Gibbs, 2013).

Resolving such differing incentives and allocation issues can be tricky territory as in some jurisdictions decision making procedures must explicitly separate distributional and allocation effects from the prioritisation task (Gibbs, 2015). For example, the common application of cost–benefit-analysis (CBA) ignores allocation of values in the analyses, and then considers distributional impacts *post hoc*. This approach implicitly assumes that the best economic use of funds is sought, rather than what it means for individual stakeholders. However when prioritisation analyses involve direct input from a range of stakeholders, these stakeholders are rarely individually interested in what might be the best economic outcome, and far more interested in protecting private property rights and special interests. Therefore understanding the incentives and special interests up front, and particularly the potential implementation barriers up front can help to avoid lack of uptake of more naïve adaptation strategies.

Applying housing values

Quantitative methods of valuation used for the determination of actions require estimates of values at risk. In coastal climate adaptation studies, one of the largest set of values is associated with private house dwellings and commercial properties such as retail outlets or shopping malls. Therefore using the best estimates of these values can be critical in the quantitative prioritisation assessment.

One approach that has been used to incorporate these values is to use market-derived house prices based on historical records of sales or transactions. The use of market transactions to obtain prices in CBAs is generally seen to be a robust approach of assessing value (Hansson, 2007). By comparison the difficulties in pricing marginal environmental values is a at least partially a result of a lack of a market to trade environmental goods and services, which itself is a consequence of a lack of tradable property rights for most ecosystem goods and services (Hanley et al., 1995).

However in this case using historical market transactions of houses and dwellings to determine present and future value can be problematic. This is because if information on future, climate-induced inundation risk is not widely available then house prices will effectively be risk-uninformed. In many nations realtors are positively incentivised not to reveal information on future inundation risk as their income through commissions is directly proportional to sale prices. Many local governments have also been reluctant to generate or release information on coastal vulnerability as a result of a fear of recourse from property owners whose perceive a threat to the value of properties as a result of the release of such information. For example, in the state of Queensland in Australia, a local government planning scheme in Brisbane (Moreton Bay Regional Council) that sought to restrict new development in locations highly at risk from future sea level rise was recently overturned by a local politician responding to pressures from property developers. Whilst overturning these development restrictions may incentivise new economic activity that will have short term benefits to the construction and development sector, it will do little to adjust property prices to the future risk.

Hence whilst in some nations such as the US, flood and inundation maps are widely available, in other nations such as Australia such information can be unavailable to some prospective house purchasers. In nations where flood maps are available, these are also commonly not yet informed by projected climate change induced changes to rainfall and sea levels.

Therefore in many coastal regions where efficient and functioning property markets operate, the present and historical prices of foreshore real estate do not commonly reflect the future risk to these assets. In some cases, property transaction prices may actually be inversely proportional to the risk-informed prices as houses closest to the foreshore can command the highest prices but may be most at risk in the future. This implies that using historical house prices in this case is probably not the best approach.

This shortfall can be addressed by having a separation in time between the generation and release of information of inundation likelihood and the assessment of coastal adaptation options. In such cases more recent house prices should reflect this new information and be more risk-adjusted. Clearly then having these studies performed concurrently and then using historical house prices as indicators of future value is not advisable.

Using rent prices can be more responsive than sales prices and hence often more suitable. As leases are commonly only a single year in duration, rental prices are also more often aligned with annualised insurance contracts which themselves are possibly the most accurate indicator of risk-adjusted value.

Another approach is to consider indicators of the economic contribution rather than prices as such. This is especially the case for residential housing stock, the economic contribution of which can be mostly restricted to the construction of new housing. In the case of community coastal climate adaptation studies of existing housing stock, using risk-uninformed historical house prices implies that the problem being solved focuses on trying to protect or recreate private value in the face of new risks posed by climate change. Whilst there are clear political drivers of diverting government funds to this end, governments are faced with addressing allocation and distributional issues whereby at least in developed nations where coastal housing stock tends to command high prices, the issues becomes one of spending government funds on recreating or protecting private assets that often provide little economic contribution. This can also create a moral hazard, as discussed below.

Valuations in MCAs

An increasingly common approach to developing a prioritisation of actions is to use a multi-criteria analysis (MCA). MCA involves designating important social, economic and environmental values and trading these weighted values off against one-another.

The application of MCAs has increased over recent decades. It is possible that this is largely in response to perceptions that other similar analyses such as CBA exhibit difficulties in incorporating social and environmental externalities. However like CBA, MCAs have a number of well-understood, but often not acknowledge shortfalls including a lack of repeatability (a fundamental tenant of the scientific process), and transparency and rigour when incompatible social, economic and environmental values are traded-off in the analysis (Gamper and Turcanu, 2007). As a result, in Australia the government guidelines on developing and assessing policy and regulations do not recommend the use of MCAs when undertaking regulatory impact assessments.

MCAs undertaken in workshops with stakeholders are also popular as they are seen as a way to engage key stakeholders in the decision making. Developing estimates of the key values in a workshop setting with stakeholders clearly has advantages in terms of engaging the community and stakeholders. However once again this implicitly assumes that the participating stakeholders have a good understanding of the problem, are not representing special interests (as most are), and are risk-intelligent (as most aren't; Kiker et al., 2009). In my experience stakeholder MCA workshops result in the generation of a values map of the short-term special interests that happen to be in attendance at the workshop at the time rather than an unbiased representation of the present and future costs and benefits of options and realistic assessment of the trade-offs.

One approach to finalising a ranking of actions based on the results of an MCA is to apply a CBA to the top ranked or top ranking options. As an MCA does not actually quantify the costs and benefits of options, a CBA is a common approach to apply. This can be a good approach. However, if social and environmental considerations were important enough to change the prioritisation in the preceding MCA, then they need to be encapsulated into the CBA. An example of this may be parks and recreation public spaces or beaches. If these are highly valued by community members, and hence in the MCA protecting these is seen to be one of the most important considerations by comparison to say protecting or relocating other assets, then these values need to be reflected in the CBA. If this is not done then the case to government for financial assistance will be unrepresentative as it will not contain the highest values. Therefore in order to be internally consistent, if social and environmental factors are used in the MCA then they need to be valued in the CBA.

Incorporating these values into CBAs can be problematic, but not impossible as the acceptance of contingent valuation approaches is steadily increasing (e.g. Heal, 2000).

The differences between say the hyper-rational application of CBA whereby only monetised market value costs and benefits are used, and MCA involving extensive stakeholder input is important to understand. The first seeks to find the best societal economic outcome. The second approach seeks to find a compromise between the varied special interests represented in the process. The first is exposed to lack of consideration of distributional impacts, which can thwart implementation and uptake, and the second is overly exposed to special interests, is often unrepeatable and loses sight of optimal economic outcomes.

Common shortfalls when applying the fix and forget approach

The second set of issues or shortfalls are a direct consequence of the common approach to developing climate adaptation strategies that involves developing a set of plans (retreat, protect, or manage) at a point in time, and then implementing these through the development of capital works plans, business continuity plans and other similar planning instruments. A key attribute of this approach is a lack of consideration of future uncertainty in both climactic conditions, but also changes to social and economic factors and how these interact with one-another. This fix and forget approach is derived from business management disciplines which typically focus on developing and implementing a one-off plan, but typically understate the monitoring and learning components of management.

As highlighted by one of the reviewers of this work, more often than not when applied to climate adaptation, the 'fix and forget' approach ends up becoming more of a 'plan and forget to implement' approach.

In response to this linear form of management, the idea of adaptive management was developed in the late 1970's (Holling, 1978). Adaptive management is characterised by learning by doing, setting up parallel but different response or management actions and then subsequently learning from the outcomes, and establishing formal monitoring systems so that knowledge is progressively improved over time; thus reducing uncertainty over time (Walters, 1986). Park et al. (2012) have considered this approach with regards to climate adaptation. This approach is the antithesis of what commonly occurs today in climate adaptation planning which typically goes as follows: someone decides that a climate adaptation plan is required (often to manage political risk), commissions the development of a climate adaptation plan, a plan is developed and follow-on actions recommended, and often subsequently ignored. Stakeholder questions on how climate risk is being managed are then directed towards the climate adaptation plan, the recommendations of which may or may not have been implemented. Either way, the risk as assessed at the time often remains unmanaged, and changes to this risk profile arising from the realisation of uncertainties are ignored as there is no mechanism or process to either understand these evolving risks, and no formal learning from previous adaptation responses.

The remaining shortfalls that typically occur in adaptation planning are a result of the application of this linear management process. These are intended to be complimentary to the more general set of barriers identified by for example Willows et al. (2003), Moser and Ekstrom (2010) and Gibbs et al. (2013).

Selecting a single option or pathway to follow in perpetuity

As highlighted above, partly as a result of increasing levels of management and complexity, community and resource managers increasingly seek one-off solutions that require no ongoing management obligation or liability. This also partly explains the preponderance of hard engineering coastal protection options such as seawalls as they can be constructed once and require very little ongoing maintenance. However, these tend to be lock-in options and often preclude the implementation of other future and possibly better options.

It is therefore common that a single option is selected and pursued in perpetuity. However as highlighted above in many cases a combination of options both in space and time may be appropriate. For example a possible pathway is to restrict asset intensification up to a specified mean sea level, after which a retreat option may be considered. Similarly, a short term option may be to relocate some structures further landwards on existing land sections until the risk becomes problematic (defined by a pre-determined trigger level), after which hard engineered solutions many be appropriate.

Therefore consideration of hybrid options as opposed to either solely retreat, or protect, or manage is a reasonable course of action in many cases. Even better would be the adoption of a formal adaptive management process that assimilates changes to both environmental and social-economic conditions, but also learnings from other regions facing the same issue.

Pathway lock in and perverse incentives

The determination of priorities for climate adaptation action for coastal communities and infrastructure commonly do not account for the potential generation of perverse incentives or pathway lock-in.

Perverse incentive are created when polices are developed that incentivise actors to behave in a manner that leads to outcomes that are inconsistent with the objective of the policies (e.g. Troutman et al., 1999). Policy lock-in occurs when policies that restrict future policy options are implemented (Liebowitz and Margolis, 1995).

There are two key perverse incentives with regards to coastal climate adaptation strategies and policies. Both of these relate to the 'protect' adaptation option that involves the establishment of hard engineered protection such as seawalls.

The cost of seawalls is strongly and directly proportional to the length of coastline being protected, and only weakly proportional to the economic intensity or type of the built assets that are being protected. Therefore for coastlines with high economic intensity such as high-rise buildings or major industrial facilities that are expensive to replace but have relatively small footprints, coastal protection quickly becomes the most cost-effective option. This is particularly the case if negative alongshore impacts resulting from the establishment of seawalls and not included in the analysis of options. By contrast, for coastlines featuring low value structures dispersed over long coastal stretches, coastal protection is often less desirable as the costs can far outweigh the replacement or relocation value of the assets at risk.

Therefore, asset owners who seek to not undertake coastal retreat as the preferred adaption strategy or policy are positively incentivised to increase the economic intensity of coastal development in order to achieve a threshold whereby coastal protection becomes the most cost-effective adaptation policy. Coastal communities, or sections thereof, can therefore anticipate the development of future adaptation policy and act to increase the economic intensity of the coastal built environment to ensure that their preferred adaptation policy is chosen at a later date (Gibbs et al., 2013). This results in more economic activity being at risk over the long term.

This effect also operates on the scale of individual assets or facilities. As highlighted above, so-called asset anchoring (Gibbs, 2013) occurs when an individual asset or facility (for example a hospital or industrial facility) at risk in the coastal zone chooses the coastal protection adaption option in order to maintain occupation of a coastal site. This then incentives the owners of adjoining private dwellings to argue for the same hard engineered adaption option even though a more cost-effective option for these lower economic intense dwelling may be to retreat.

Pathway or policy lock in occurs when the selection of a coastal adaption pathway or option in the short-term inadvertently restricts the application of different options in the future.

Once a large scale coastal retreat policy has been implemented, it is essentially irreversible. This policy requires large up-front capital investment which represents a sunk cost. From a hyper-rational economics perspective implementing this option implicitly discounts other possible future options and hence may not be the most economically efficient long-run option.

Similarly, the do nothing option is very economically efficient up to the point where a major inundation event occurs and government funds are required for reconstruction or refurbishment. Any future options that are implemented following such an event will require funds over and above these committed restoration sunk costs. If the no-change policy option is pursued and a major inundation event occurs, the political response tends to go one of two ways: Either the response is 'we cannot let this happen again' and adaption options are implemented immediately (as in the case of New York following storm Sandy), or the alternate response is that it is assumed that a similar event is unlikely to re-occur anytime soon (within the same political cycle) so let's do some repairs and continue with the no-change policy. Both responses are typically not well informed by the true risk profile and tend to be managing political risk rather than actual risks.

Once again, adopting a formal active adaptive management program would alleviate many of these problems.

Summary and concluding remarks

Committing funds to studies that do not underpin or measurably contribute to demonstrable future climate risk reduction is unhelpful for elected officials, land use and town planners, and owners of assets potentially at risk. Such studies can also lead to reputational and credibility damage to practitioners and the research and practitioner community in general. Whilst it is clear that deliverers of climate adaptation studies are well-meaning, by delivering studies that are ultimately unhelpful can ensure that coastal communities become unnecessarily and increasingly financially at risk.

Adaptation planning is currently typified by the linear management approach of assessing the vulnerability or risk, developing a risk mitigation plan, recommending a series of measures and then assuming that the risk is being managed. Whilst it is generally accepted that risk-based frameworks are suitable for climate risk management, the more general linear management framework of assessing the risk, developing a single adaptation strategy, and then recommending the implementation of this strategy over time is questioned. A number of the common issues identified here are a direct consequence of applying this linear 'fix and forget' management approach.

The unsuitability of this linear management approach for managing ecosystems has been identified for decades, and an alternative approach in the form of active adaptive management proposed in the 1980's. However, as highlighted by Gregory et al. (2006), many if not most of the applications of active adaptive management have failed to meet what might be considered minimum standards for adaptive management. This lack of formal application of adaptive management is repeatedly been highlighted to be a result of several formidable implementation barriers. Hence whilst adaptive management appeals as a theoretical construct, actually implementing this framework has proved problematic.

One of the main implementation barriers has been that active adaptive management requires multiple management practices to be implemented in parallel so that the best performing intervention or management response can be determined quickly. For example, In the case of coastal climate adaptation one could consider three at-risk coastal communities embarking on three different adaptation strategies (retreat, protect, or manage) and over a specified time period in order to identify which strategy has been most effective. Similarly, small low-cost options could be implemented and then monitored for effectiveness. However this would require some communities to embark on experimental adaptation pathways; some of which are likely to be sub-optimal and potentially costly in the long-run. This strategy could lead to potential litigation as these other communities essentially suffer in the name of the greater good. However under the present approach, each community is considered a new and isolated problem and adaptation plans are largely generated without the knowledge of the performance of other approaches in other regions.

Despite the obvious long-term advantages of active adaptive management approaches, the implementation of active adaptive management frameworks for climate adaptation face the same formidable implementation barriers that this framework faces for other environmental management problems. Therefore it is realistic to expect that much of the adaptation efforts will continue to be directed towards the linear management approach. This implies that most, if not all of the issues and shortfalls identified here will continue to be problematic.

In terms of the analytical decision-making method applied, for example CBA or other approaches such as scenario analysis, there is no single approach that is without problems. Hyper-rational approaches such as CBA are often in alignment with government accounting and assessment standards but face the well-known shortfalls of discounting and addressing externalities. Similar real options approaches often prefer 'just-in-time' or Cornucopian type responses that allows funds not spent on climate adaptation to be 'better' spent on other government services.

By contrast, many feel uncomfortable with just-in-time strategies, fearing that not enough will be done before climate change-mediated natural disasters occur. Proponents of these more Malthusian ideologies often advocate a more Precautionary approach and adapt early responses, arguing that as a result of uncertainty in the timing or occurrence of future events, being better prepared will be more cost-effective in the long run. However this approach does not consider distributional issues and the real time economic conditions. Neither is this approach likely to be as effective as an active adaptive management approach.

For practitioners delivering climate adaptation studies, it is essential that practitioners understand both their own internal biases towards either hyper-rational or more Precautionary approaches and the biases or preferences of recipients and users of climate adaptation studies and plans. This is not necessarily an easy request as recent neurological and psychological research has demonstrated the extent of generally unrecognised neurological biases in decision making and our common lack of appreciation in how these heuristics operate (Kalineman, 2011; Preston et al., 2015). In particular, whilst we may think we are acting in an unbiased and rational manner, the recent identification of these embedded human heuristics provides an alternate view of our ability to comprehend and manage risk. It is not difficult to imagine a neo-classical economics trained hyper-rational recipient or funder of a coastal climate adaptation study receiving a report that advocates a precautionary approach accepting the assessment of vulnerability, but rejecting the proposed mitigation actions.

Therefore, in addition to the particular shortfalls identified in the work presented here, it is recommended that practitioners and providers of coastal climate adaption studies and plans understand their own individual and organisational heuristics, and those of recipients of reports.

Finally, as highlighted above it is easy to argue that the most appropriate theoretical construct for managing the risks of climate change is an active adaptive management framework. Unfortunately implementing active adaptive management for climate adaptation is exposed to the same substantial implementation barriers that the application of adaptive management to other environmental management problems face. However, it would be helpful to see more consideration of opportunities to implement active adaptive management for climate change risk management problems.

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